Results from NASA Agile Teams Study

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In order to meet the demands of the current global economy, a study of agile teams at NASA was conducted by the NASA Engineering and Safety Center (NESC) to explore how the Agency can become more adaptable and flexible due to several influences, including the maturity and availability of digital tools and NASA's increased reliance on commercial providers. NESC Technical Discipline Teams (TDTs) perform annual studies to understand the needs of their stakeholders, establish a state of the discipline, and inform strategic planning efforts. As part of the 2022 interview series, the Systems Engineering TDT utilized the dissertation work of Dr. Jackelynne Silva-Martinez that focused on NASA agile teams. The Systems Engineering TDT partnered with the Software and Human Factors TDTs on the formulation of interview questions and subsequent solicitation of customer inputs, which helped attract diverse agile teams across the Agency. 34 participants were interviewed, including civil servants and contractors, with open-ended questions related to their teams' adoption and transition to agile. Participants were also questioned about their perceptions of the implementation of agile approaches across the Agency. Results showed a consistent framing of agile as incremental knowledge growth, a way of showing progress, and as the incorporation of frequent customer feedback. However, participants emphasized a lack of a common understanding of agile across the Agency, which sometimes caused managers and engineers to be reluctant to accept and support them. Results also showed the most successful agile teams had formal training with over five years of agile experience, used retrospectives, and tailored their agile processes for their specific situation and needs. This paper provides details of the interview responses gathered in the study and suggests actions for NASA to become more agile.

I. Introduction

The NESC was established after the Space Shuttle Columbia tragedy on February 21, 2003, to address a systemic issue that had contributed to several high visibility spaceflight mishaps and close calls, the absence of an independent Agency-level engineering resource that could quickly form embedded 'tiger teams' to help programs and projects tackle the most serious technical issues facing the Agency. Requests for NESC assistance originate from anywhere within the NASA civil servant and contractor workforce. On a few occasions, the NESC has been asked to help other government agencies. An example from October 2013 was an NESC-led team that provided detailed design inputs (through the State Department) for the rescue capsule developed and built by the Chilean Navy to bring 33 miners safely back to the surface after being trapped nearly a half-mile underground for 69 days.

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The primary purpose of the NESC is to perform value-added independent assessments and to provide technical expertise to NASA projects and programs when a gap exists. To fulfill this purpose, technical discipline teams (TDTs) for 20 disciplines form the pool of 'ready experts' from which the personnel needed to resolve complex technical issues can come together. TDT membership includes civil servants, contractors, academics, technical experts from other government agencies, and industry consultants. NESC's goal is to achieve safety through engineering excellence.

The responsibilities of NASA's technical fellows include capability leadership for the resources required to carry out NASA's mission (i.e., technical expertise, tools, specifications, standards, processes, methods, and infrastructure). Capability leadership includes an annual evaluation of the state of the discipline to put strategic and tactical initiatives in place to preserve and improve these capabilities for future programs. Several TDTs, including guidance, navigation, and controls (GNC) and systems engineering, had been using voice of the customer interviews to support these discipline evaluations for several years. An opportunity arose to evaluate agile teams focused on those disciplines and others, so the decision was made to sponsor and support the agile teams study summarized in this paper.

In addition, NESC works closely with commercial service providers for the commercial crew, commercial cargo, and Moon to Mars (Artemis) programs. In general, the commercial providers have incorporated many agile processes to be successful. As early as 2020, a series of interviews with stakeholders external to NASA identified the need for more agile systems engineering and Model Based Systems Engineering (MBSE) implementation. However, most responses were more centric to engaging MBSE and other digital tooling opportunities [1]. Three years later the industry voice was essentially silent on MBSE and digital engineering, and strongly focused on making systems engineering more agile and adaptive, in both technical and programmatic domains [2]. The complexity of how we improve the way we work is not exclusive of tooling or culture. Therefore, the study objective was to learn lessons from NASA teams transitioning to agile practices, as well as the processes, methods, and results from their implementation.

II. Methods

The study was led by Dr. Jackelynne Silva-Martinez, who was researching outcomes and leadership characteristics from NASA agile teams [3,4,5]. Data collection was performed via interviews using open-ended questions developed with inputs from the Systems Engineering, Software, and Human Factors TDTs. The questions, as shown in Table 1, guided the conversation during the interviews with the participants. Each agile team had their own unique situation, including technical constraints, schedule deadlines, issue complexity, and team member availabilities, which prompted different follow-up questions as the interviews progressed.

	Introductory Questions
1	How do you define "agile"?
	What do you personally like most about working in an agile team?
	What is the most rewarding aspect aspect of Agile?
	What is the most challenging aspect of Agile?
2	Please provide specifics of your team goals or products when using agile
	What are your team goals?
3	Have you or your team established your own agile process(es), or work from a prescribed/predefined process?
	Do your agile team members have the same specialty or different specialties and functions?
	In-Depth Questions
4	How do you measure your agile team's performance?
	What metrics does your team use?
5	Who are your key customers and how often do you receive feedback from them?
	What type of customer feedback helps your agile team better iterate your product or service?
	What is an average frequency in which your agile team submits increments of the deliverables?
	How did you determine the timeframes of the increments and iterations? (e.g. sprints in Scrum)

6	How does communication flow down to your team to make it part of the backlog priorities?
	What agile techniques do you/your team use to facilitate decision making and why?
	What agile aspects make it difficult to make decisions and why?
7	Describe your approach in the management and oversight of your agile team?
	How well is the approach working for management and oversight of your agile team?
8	What is the level of commitment and transparency of team members in your agile team?
	How do you/your team ensure collaboration and maintain cohesion among team members?
	Is your team self-organized? Please provide examples on how your team exhibits self-organization.
9	What is your team's perceived value and contribution to your customer(s)?
	How does Agile help your team provide increasing value (perceived benefit) to your customers?
10	How was the transition for you/your current team to applying Agile?
	What were/have been the keys for successful transition to applying agile for your team?
	If it was not successful, when did you decide agile was not for your team or your project?
	Describe your work environment that allowed agile to be fostered instead of previous traditional methods (e.g. your organization is open to change, management encourages initiatives)
11	How well have leaders/managers supported your agile team?
	What did leaders/managers do to support your agile team?
	What did leaders/managers do to hinder your agile team?
12	If using a hybrid approach (a combination of agile techniques and traditional processes): How is it working for you and your team?
	What aspects of your project are traditional and what aspects are agile?
	Why are you/your team using a hybrid approach?
13	What type of agile training have you or your team had?
	Have you used an agile coach and does your team have access to agile coaches?
	After any formal agile training, was the team able/ready to execute?
	How has agile training impacted how your team functions/works together?
	Closing Questions
14	What kind of background (technical competencies, leadership qualities, culture, attitudes, etc.) do you think is needed to be able to become an Agile team?
15	How well do you think NASA is prepared to work with agile commercial companies?
	What key factors would need to be taken into account if an agile mindset is implemented across the Agency?
	What advice would you give to a new team that wants to adopt Agile?

Table. 1　Interview Questions for NASA Agile Teams

The interviews were conducted by Dr. Silva-Martinez and Mr. Pawlikowski via Microsoft Teams video and audio conference calls from June to August of 2022. A total of 34 participants from teams across the 10 NASA Centers participated in the study, including four consultants who helped train NASA teams to effectively adopt agile approaches. Figure 1 shows the distribution of interviewees by NASA centers.
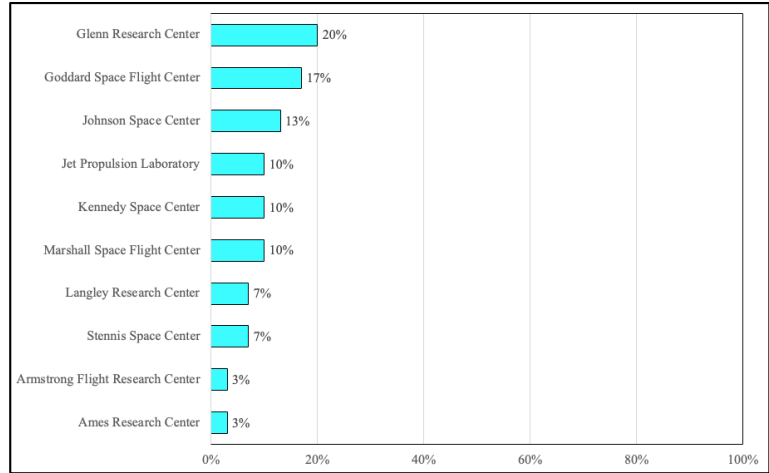
Fig. 2 Interviewee Distribution Across NASA Centers

NASA participants were a combination of team leads and team members, with current, recent, or past experience on an agile team. Backgrounds of the participants included project managers, discipline experts, flight software design leads, system integrators, configuration management leads, verification leads, safety engineers, human factors engineers, structural dynamics experts, hardware development engineers, software assurance leads, automation design engineers, model based systems engineers, and product owners. These skills were grouped into software development, systems engineering, and other backgrounds as shown in Figure 2. Knowing that agile has its origins in software development, it was no surprise that participants with software backgrounds had the highest representation rate.
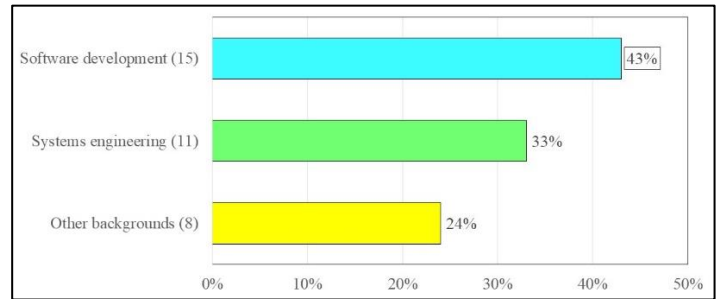

Fig. 2 Agile Teams Study Participant Backgrounds

III.   Results Summary and Discussion

Given that the study used open-ended questions, an effort was made to quantify the answers, which had overlaps in the responses of various participants. Selected graphs with the results from the interviews are shown in the appendix. These results were susceptible to the interpretations of the interviewers. To limit any potential bias, NESC used Mr. Pawlikowski, an independent contractor from Harlan Brown & Company, Inc., who has performed over 30 voice of the customer studies for NESC TDTs and other NASA clients [6]. The appendix shows several examples of specific study results, and the next sections summarize key findings with some discussion.

A. Successful Agile Teams

Indicators that agile teams have been successful in their operations include:
- Having formal agile training and/or a trained agile facilitator
- Using retrospectives
- Team leads having experience with agile

- Tailoring and adapting agile to the unique situation of each team
- Being self-organized
- Having a scrum master
- Being customer-centric and having customer success as their main focus
- Tracking customer satisfaction often, including gathering informal, qualitative feedback

Figure 3 shows examples of quotes described by the participants about increasing value. Successful agile teams felt empowered to provide their team members something of high value (e.g., contributions to a major NASA mission, an internal award, or recognition by senior management). Relying on constant communication, high levels of accountability, and being collaborative were three other key characteristics often described by the participants.

How does Agile help your team provide increasing value (perceived benefit) to your customers?
"It **forces you to talk with customers more frequently and iterate on the design** and if needed revector you into another direction."
"**Customer feedback at each meeting throughout the process** is how you can provide increasing value."
"**Frequent deliveries and working software.** Here is a small bit for now. Having that steady delivery stream."
"It allows you to **assess where you are and where you want to be** and then what's still needed to get there."
"The first thing the team really responded to was the **daily tag ups** vs. only once a week."
"**We have something we can show that works** that gives them confidence that they can trust us."
"**Daily standups and forced communication** was a huge factor to provide value."
"**Customers that are super engaged take ownership in it** because they were involved all along the way."
"**Doing retrospectives** because it **forces you to look back at what you have been doing.**"
"Being able to **adjust to what the customer wants.**"
"It **freed them [team members] up** to be a little more independent and more creative and **gave them space to come up with their own ideas.**"
"**Breaking down work into more manageable pieces** and **getting more interaction** between the team members."

Fig. 3 Participants' Quotes Related to NASA Agile Teams Providing Increasing Value

B. Transition to Agile

Figure 4 lists selected quotes describing the transition to agile. Keys to teams' success in transitioning to agile include:
- Using pure agile (versus a hybrid approach that merges waterfall and agile)
- Tracking customer feedback often (gathering informal qualitative feedback from customers)
- Having something to show that the team is making progress
- Starting out small and staying small (less than 10 members)
- Having managers who support the agile team by getting people to think about it, being open to trying a different approach, trusting, and empowering the team

What have been the keys for successful transition to applying Agile for your teams:
"Realizing that **tailoring things is OK.**"
"**Cohesiveness with NASA leadership** to understand what their goals are."
"**A shared sense of ownership for the path we are going down.** Team members think – 'I am a participant in solving the problem'. **Having a stake in the new way they are working** allows them a better sense of understanding why."
"**You have to do a mind flip** moving from waterfall to agile."
"**Key was our management being open to us undertaking those agile processes.**"
"**Getting that buy in from leadership and customers upfront** to identify expectations for what agile is going to look like and the expected level of review because change can scare people."
"**Management buy in** and encouragement."
"**Retrospectives** more than anything else have been a driver for a lot of our team's success."
"**Frequent communication** to the project office, **team building and making sure that every member of the team knew what role they played** and the importance of that role"
"**Keeping it simple** and then using common patterns or design solutions."
"**We worked out a successful hybrid method** combining both agile and traditional approaches, **coming to agreement that would satisfy everyone.**"
"**People's roles and responsibilities were defined and communicated well upfront.** We got people to buy into their roles and responsibilities."
"**#1 has been open communication with customers.** #2 is **getting teams to buy into the agile concept** and process."

Fig. 4 Participants' Quotes Related to NASA Teams' Transition to Agile

C. Major Observations

The work environment that allowed agile practices to be successful had higher than average buy-in and support from management and stakeholders. A key for agile teams to thrive is being provided autonomy in a very collaborative work environment. Value and success in agile are tied to the team, as shown with the quotes in Figure 5.

> "**It's the team** that will bring home the project."
> "**The concept of team** is what I value the most about agile."
> "**None of this would happen without the team.** I could not do this alone. **They are the value.**"

Fig. 5 Participant Quotes Related to Success Being Tied to the Team

In response to how well prepared NASA is to work with commercial service providers, the responses were mixed but promising, as shown in Figure 6.

> "**NASA leadership is becoming more aware and supportive for the need of that.** There are some initiatives coming out of NASA HQs transforming program management that are going to support this."
> "There is a lot of institutional inertia and we have been doing things a certain way and it's really hard to change that. However, I see a **desire to change that from many angles.**"
> "**Working [in an agile team] has been enlightening** and has helped transcend some of the NASA ways from the past. Its opening NASA's eyes to the use of agile, but **we have to be extremely more flexible.**"

Fig. 6 Participants' Quotes Related to NASA's Readiness to Work with Commercial Providers

Key factors that need to be considered if agile is broadly implemented across NASA, as shown in Figure 7, include:
- Being open to evolve things and not having everything defined upfront
- Education and training on agile mindset across the board
- Flexibility and knowing that agile is not always the right answer

> "**A major culture shift within NASA and applying agile outside of software.** NASA favors big hardware projects."
> "**Socializing people to agile and that it's working great.** We need to have more education and do presentations to **grow awareness of it so people are less scared of it.**"

Fig. 7 Participants' Quotes Related to Factors for Agile Implementation

Finally, several major issues were identified when agile teams were unsuccessful, including a lack of buy-in and trust, management turnover, and insufficient training. Decomposition of tasking to a level achievable during a sprint or breaking down work into manageable chunks is another major challenge.

IV. Recommendations

These recommendations are provided based on the results of this NASA agile teams study:
- Develop and grow management understanding and buy-in
- Communicate and promote how and why agile works by sharing lessons learned and best practices
- Use small teams with as many full-time team members as possible
- Conduct pilot programs and use early career development programs
- Increase recognition of the importance of formal training, coaches, and retrospectives
- Build awareness of agile success stories, especially those within the immediate organization
- Tailor agile for what works best for the team and provides the customers and stakeholders with the results they need
- Be open-minded, flexible, and make a sincere effort to make agile efforts work for the team

Potential future study ideas include:
- Re-contact study participants in 1-2 years to monitor perception and continued growth of their agile teams
- Quantify and clarify the key issues addressed in this study
- Identify agile practitioners, programs, and projects not identified in this survey iteration
- Contact project and program managers and other NASA leaders to understand their perceptions of agile and monitor their buy-in to agile practices

NASA has formally instituted an agile community of practice with representation from across the Agency. Sponsored by the NESC Systems Engineering Technical Discipline Team, the intent is to better understand the agile practitioner community, advance the speed of adoption and lessons learned to understand implications to current processes and appropriate next steps in digital advancement of the systems engineering discipline and its integration with software and other technical disciplines.

V. Conclusions

Agile teams are an important part of NASA's future. Teams are using agile practices to produce systems supporting crewed and uncrewed space flights, science missions, and aeronautics programs. Many NASA teams transitioned to approaches now considered agile long before they were labeled as such. A team's methodology is secondary to the outcomes of the team's efforts, including customer/stakeholder satisfaction, providing rewarding work for individual team members, and making the team itself stronger and empowered so new challenges can be undertaken. Training, experiences, tools, and methods that enable teams to meet the needs of the customers should be provided. It is important not to force-fit agile methods in situations where using more traditional methods or hybrid approaches are likely to better serve the stakeholders. In many situations, tailored processes and combinations of methods adapted for the specific needs of the team should be considered for the organization to achieve mission success. NASA's agile community of practice is one of the many efforts the Agency is doing to increase its organization agility.

Acknowledgments

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Appendix: Selected Agile Study Results

How Do You Define Agile?/Across All Sources

- Incremental knowledge growth or product development — 85%
- Incorporates constant and frequent customer feedback — 59%
- Can respond in a timely fashion to changes in requirements — 26%
- Making my team efficient, self-directing and high performing — 24%
- A mindset switch between waterfall and agile — 18%
- Following the Agile Manifesto — 9%

How Do You Measure Your Team's Performance? What Metrics Do You Use?/Across All Sources

- Tracks delivery, costs, quality, feedback, user acceptance, value and productivity — 65%
- Gathers no formal metrics from customers (does not quantify customer satisfaction) — 53%
- Gathers informal qualitative feedback from customers or PM — 47%
- Does not measure team performance — 26%
- Tracks customer satisfaction through direct customer feedback — 18%
- Requirements burndown — 15%
- Measures team velocity — 15%
- Specific mention of use of work tracking tools — 12%

What Agile Aspects Do You Use To Facilitate Decision Making?

- Constant communication and accountability — 47%
- We are highly collaborative — 40%
- Sprint planning is our key decision-making time — 27%
- Doing retrospectives — 20%
- Unsure if we tie decision making into agile/unsure what 'agile aspects' means — 13%

What Did Managers Do To Hinder Your Agile Team?

- Pushing waterfall — 38%
- Agile mismanagement — 31%
- Micromanaging — 15%
- Not being able to keep interruptions at bay — 15%
- Resources didn't meet our schedule needs — 15%

Describe Your Approach In Managing Your Agile Team

- Supportive management — 87%
- Empowerment — 73%
- Foster an open and collaborative environment — 53%
- Hiring smart people — 13%
- Have broad oversight of the project and situational awareness — 13%

Why Was Agile Not Successful or Did Not Work For Your Team?

- Lack of buy-in or trust in agile — 80%
- Management turnover — 40%
- Not enough training — 40%

Describe Your Work Environment That Allowed Agile To Be Fostered Instead of Previous Traditional Methods/Across All Sources

- Buy in and support from management, stakeholders and the team — 73%
- Team has been given a lot of autonomy/flexibility — 20%
- Its very collaborative — 20%
- We were all co-located — 13%
- Openness to on-line collaboration — 10%